Jet-Surface Interaction Test: Phase 1 Results and Phase 2 Planning

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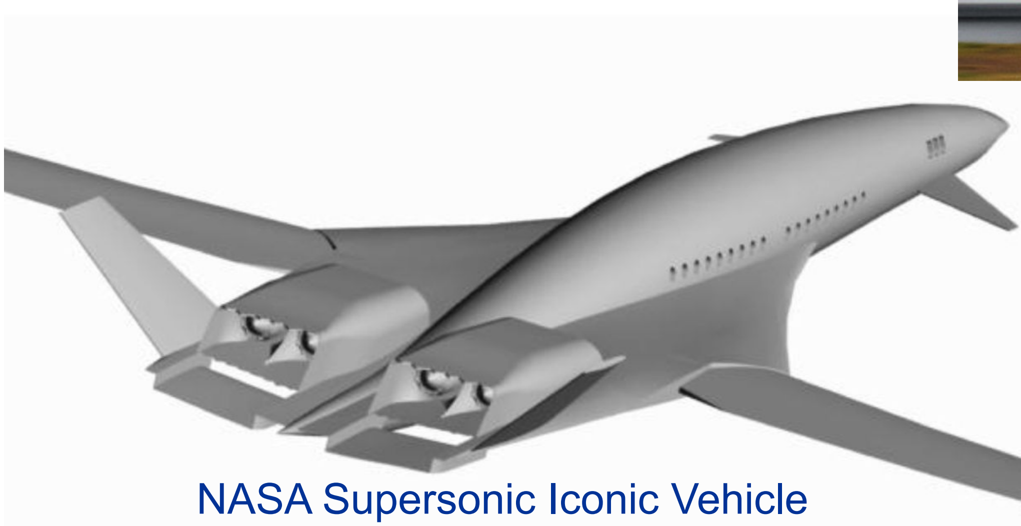
Supported by the NASA Subsonic Fixed Wing Project

Jet/Surface Interaction Noise

Noise created by the high-speed jet exhaust striking or passing near a solid surface

- Jet/Surface Interaction Noise is a problem for both current and future aircraft
- Jet/Surface Interaction Noise is a problem for sub-sonic and supersonic aircraft
- Jet/Surface Interaction Noise is difficult to predict accurately with current tools/codes
- Experimental data is limited or unavailable
- We will expand the definition to include noise noise shield and propagation issues

Boeing 787



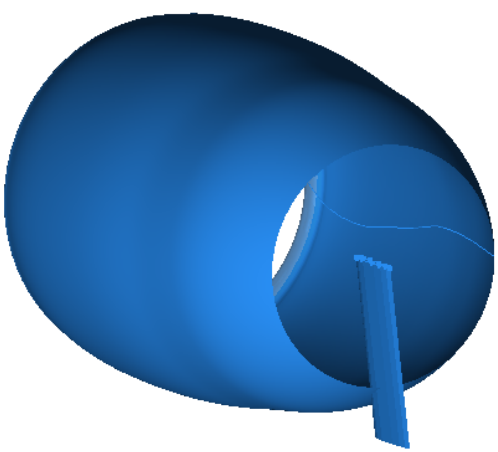
NASA Supersonic Iconic Vehicle

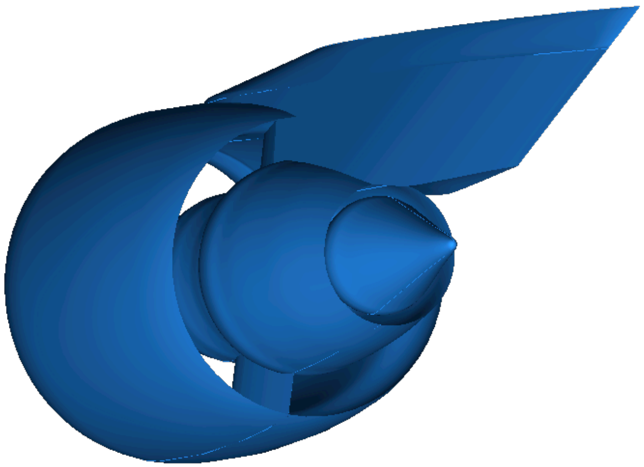
NASA AMELIA

Jet/Surface Interaction Test (JSIT) - Objective

Establish a quality dataset, noise and flow data, to create/improve/validate aircraft noise prediction codes and methods that include the affect of aircraft surfaces on jet noise

1. Include noise shielding and propagation as well as any new sources of noise
2. Many configurations possible – wings, flaps, pylons, JBD – but keep geometry simple and generic, building complexity over time
3. Investigate / develop flow measurement techniques applicable to high-speed flow near a surface
4. Test will covers several “Phases” that build on each other





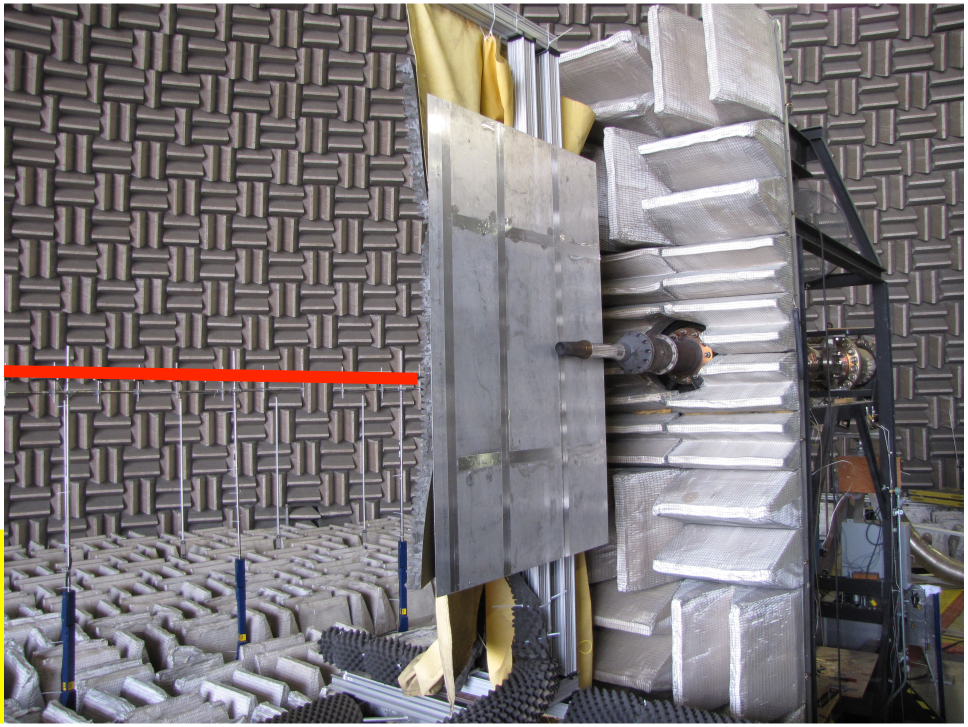
Jet/Surface Interaction Test – Phase 1

- Objectives:
  1. Acquire far-field and phased array acoustic data for a jet near a flat surface for development of noise prediction codes
  2. Acquire data for a wide range of surface positions to determine “regions of interest” for simulations and future testing
  3. Acquire transient pressure data at the surface – future flow measurement?
  4. Acquire pressure data at the surface (steady and transient) using pressure sensitive paint –future flow measurement?

Test details:

- Single geometry–flat plate parallel to the jet axis with tapered trailing edge
- Far-field and phased-array acoustic data acquired in “shielded” and “reflected” position
- Acquired data at subsonic and supersonic jet conditions for all surface positions
- Surface integrity shown by phased array

Simple geometry where complexity increases with choice of surface position and jet exit condition



JSIT Phase 1 Planning - Methodology

Provide a dataset that (1) progressively builds complexity using a single geometry and that (2) shows "regions of interest" for simulations and Phase 2 testing

(1) Subsonic cold jet – surface outside the jet – noise propagation

→ Move Surface Closer, Extend Surface →

(2) Subsonic cold jet – surface in jet plume – jet/surface noise sources and propagation

→ Increase Jet Mach Number →

(3) Supersonic ideally expanded cold jet – surface near the jet plume – supersonic flow w/o shocks

From (2): ↓ Add Heat, Same Mach ↓

Subsonic hot jet with surface interaction noise and propagation around surface

From (3): ↓ Increase/Decrease Jet Mach Number ↓

(5) Supersonic cold jet with surface interaction noise, propagation around surface and shock noise

Top View

JSIT Phase 1 Planning - Methodology

Provide a dataset that (1) progressively builds complexity and that (2) shows “regions of interest” for simulations and Phase 2 testing

(1) Subsonic cold jet – surface outside the jet – noise propagation

→ Move Surface Closer / Extend Surface →

(2) Subsonic cold jet – surface in jet plume – jet/surface noise sources and propagation

→ Increase Jet Mach Number →

(3) Supersonic ideally expanded cold jet – surface near the jet plume – supersonic flow w/o shocks

From (2): ↓ Add Heat / Same Mach ↓

Subsonic hot jet with surface interaction noise and propagation around surface

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Supersonic ideally expanded cold jet – surface near the jet plume – supersonic flow w/o shocks

From (2): ↓ Add Heat, Same Mach ↓

(3) Subsonic hot jet with surface interaction noise and propagation around surface

From the supersonic ideally expanded case: ↓ Increase/Decrease Jet Mach Number ↓

Supersonic cold jet with surface interaction noise, propagation around surface and shock noise

Top View

JSIT Phase 1 Planning - Methodology

Provide a dataset that (1) progressively builds complexity and that (2) shows "regions of interest" for simulations and Phase 2 testing

(1) Subsonic cold jet – surface outside the jet – noise propagation

Move Surface Closer
Extend Surface

(2) Subsonic cold jet – surface in jet plume – jet/surface noise sources and propagation

Increase Jet Mach Number

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Add Heat
Same Mach

Subsonic hot jet with surface interaction noise and propagation around surface

Increase/Decrease
Jet Mach Number

(5) Supersonic cold jet with surface interaction noise, propagation around surface and shock noise

Top View

JSIT Phase 1 Planning - Methodology

Provide a dataset that (1) progressively builds complexity and that (2) shows "regions of interest" for simulations and flow measurements

(1) Subsonic cold jet – surface outside the jet – noise propagation

Move Surface Closer
Extend Surface

(2) Subsonic cold jet – surface in jet plume – jet/surface noise sources and propagation

Increase Jet
Mach Number

(3) Supersonic ideally expanded cold jet – surface near the jet plume – supersonic flow w/o shocks

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Subsonic hot jet with surface interaction noise and propagation around surface

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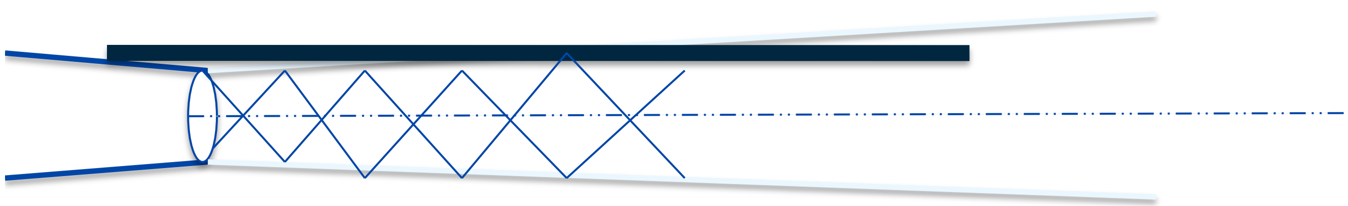
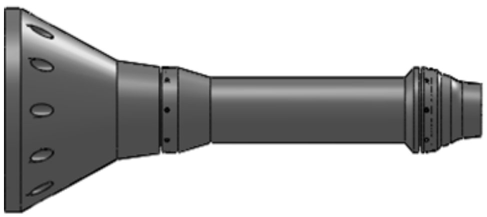
Top View



JSIT Phase 1 - Jet Exit Conditions

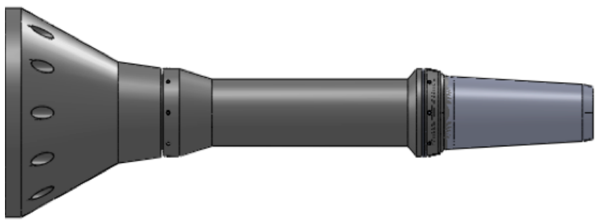
Convergent Round Nozzle (SMC000)

Setpoint	NPR	NTR	Ma	Mj
	Pj,t/Pa	Tj,s/Ta	Vj/ca	Vj/cj
3	1.197	0.95	0.5	0.51
7	1.86	0.835	0.9	0.98
27	1.36	1.764	0.9	0.68
46	1.227	2.7	0.9	0.55
9010	3.182	0.74	1.18	1.40

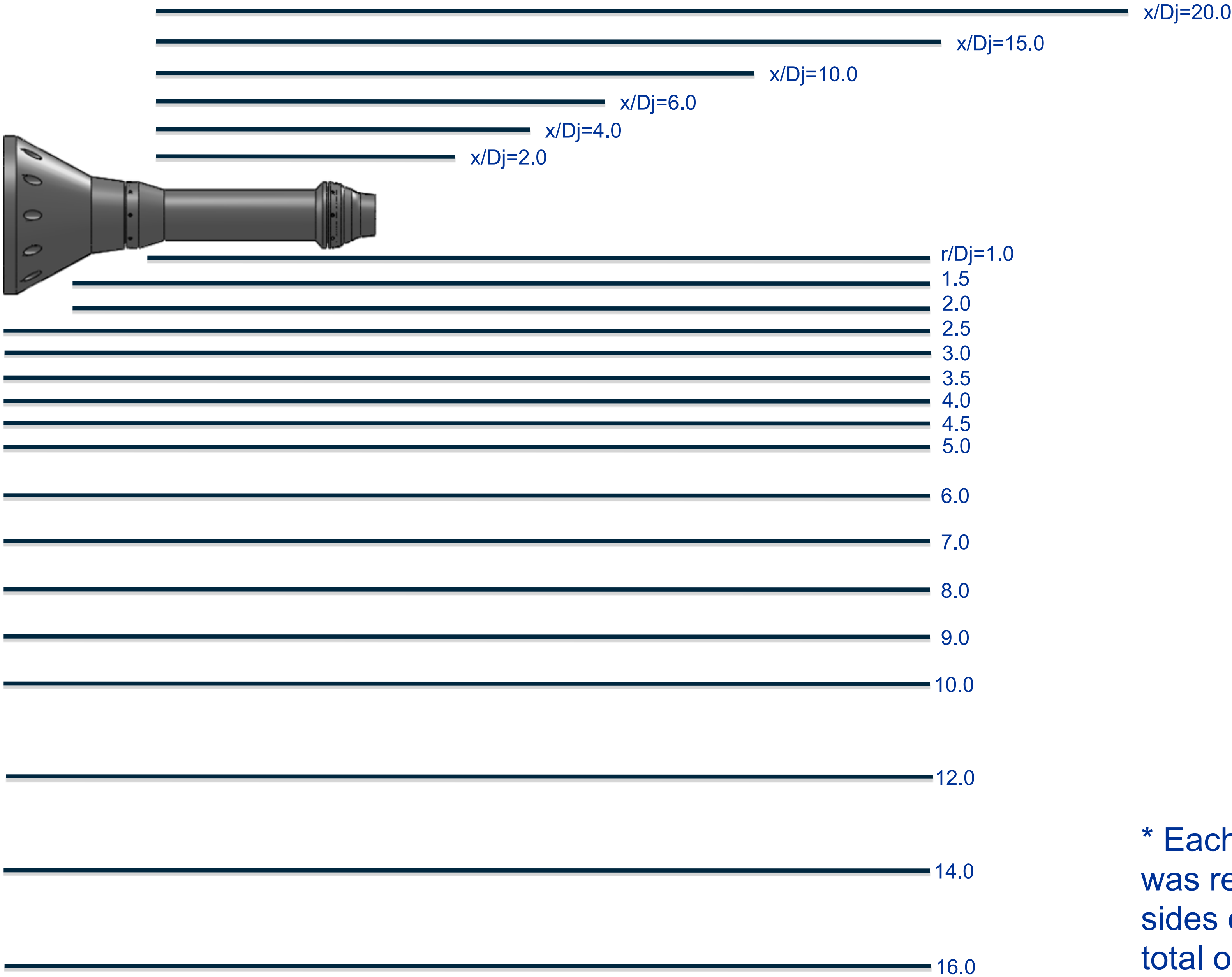


C-D Round Nozzle (SMC016), M_d=1.5

Setpoint	NPR	NTR	Ma	Mj
	Pj,t/Pa	Tj,s/Ta	Vj/ca	Vj/cj
11606	2.748	0.761	1.128	1.29
11610	3.670	0.706	1.31	1.5
11617	4.324	0.671	1.41	1.61

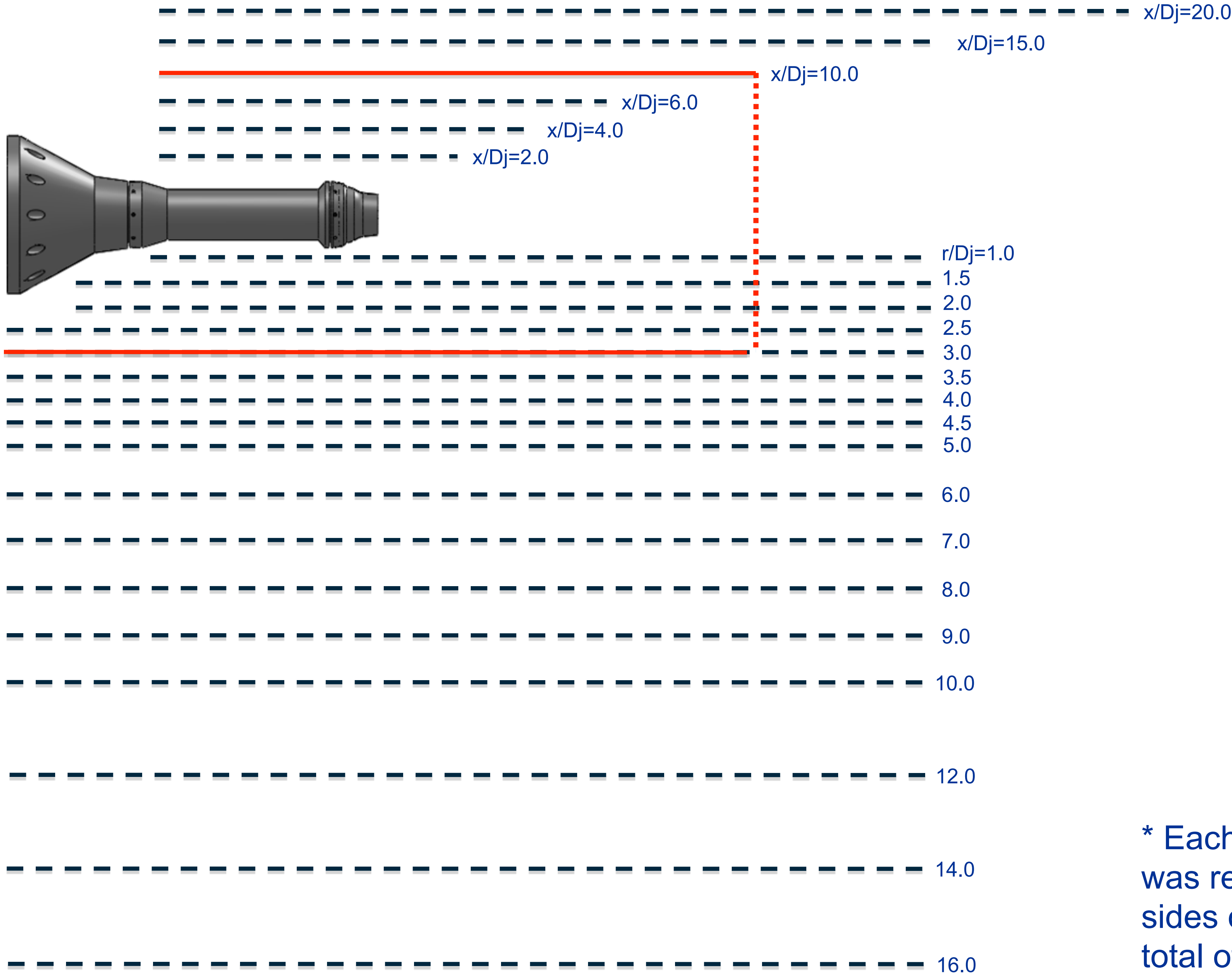


JSIT Phase 1 – Surface Positions



* Each surface location was repeated on both sides of the jet for a total of 204 positions

JSIT Phase 1 – Surface Positions

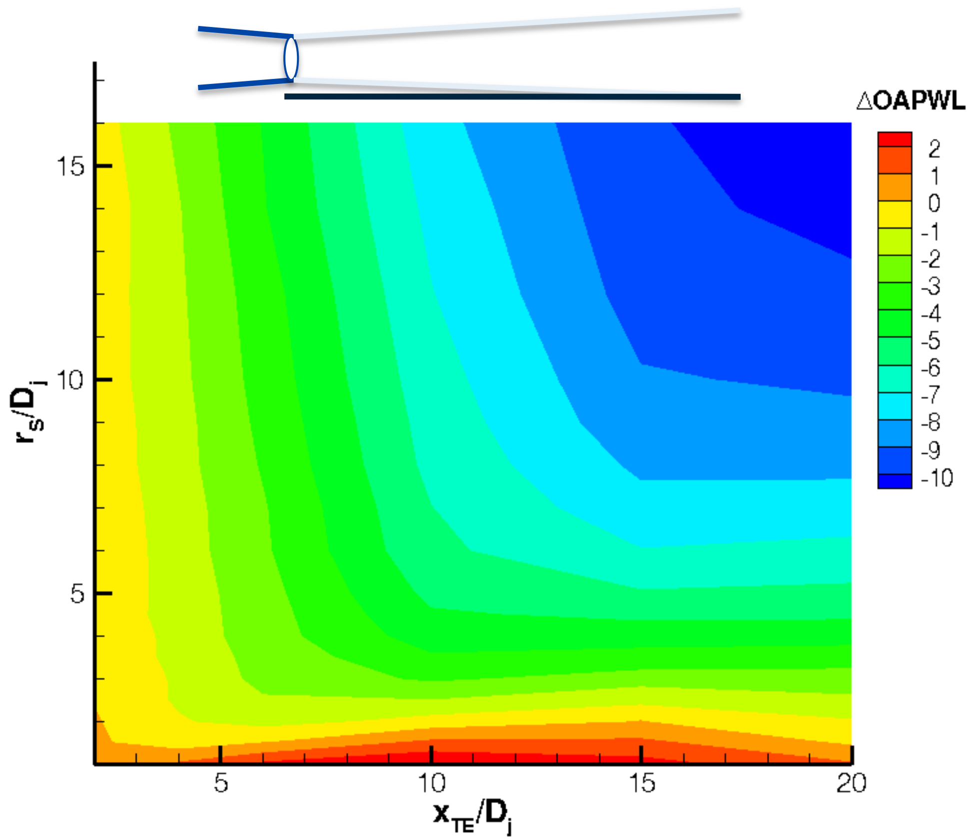


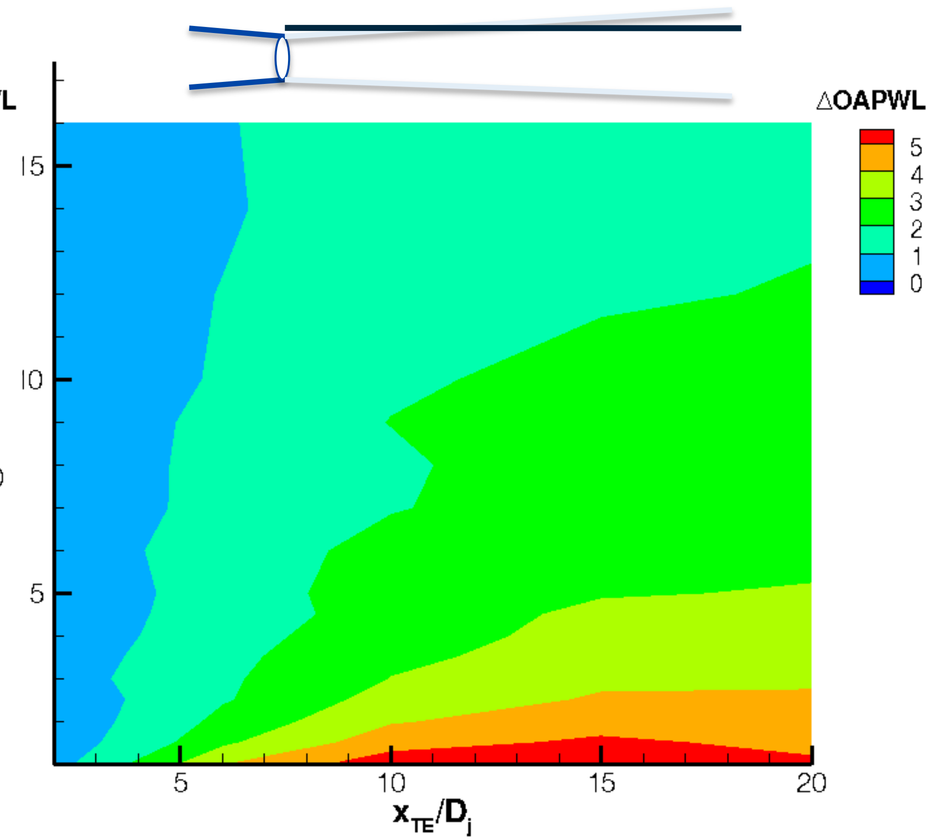
* Each surface location was repeated on both sides of the jet for a total of 204 positions

National Aeronautics and Space Administration

Overall Sound Power Level – M_a=0.9

Integrate in space and frequency for each surface position at a given jet condition to show the net effect of the surface
(balance between shielding noise and creating new noise)

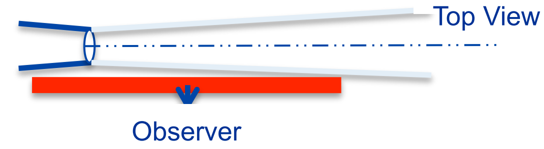


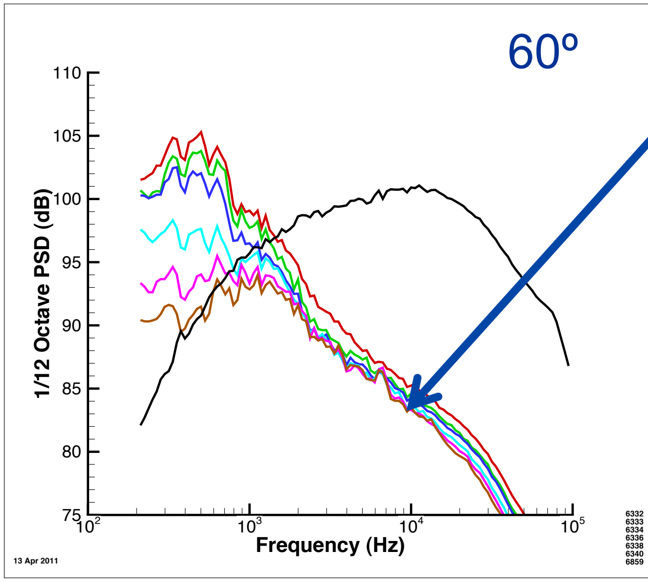


* Note the change in scales between the two plots

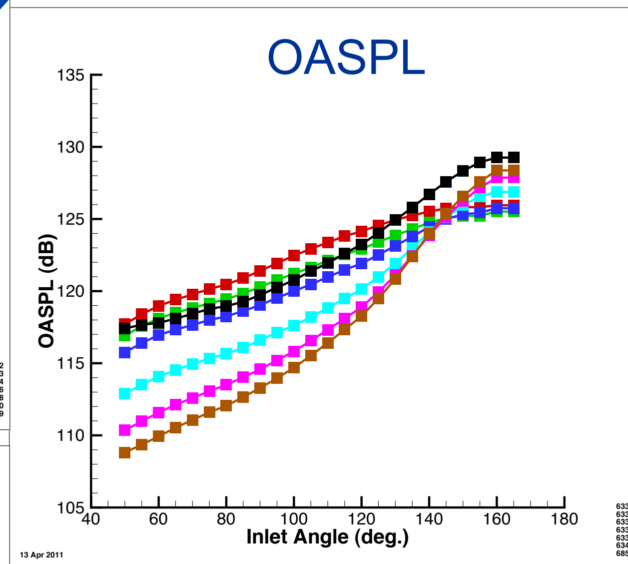
JSIT Phase 1 – Noise Shielding

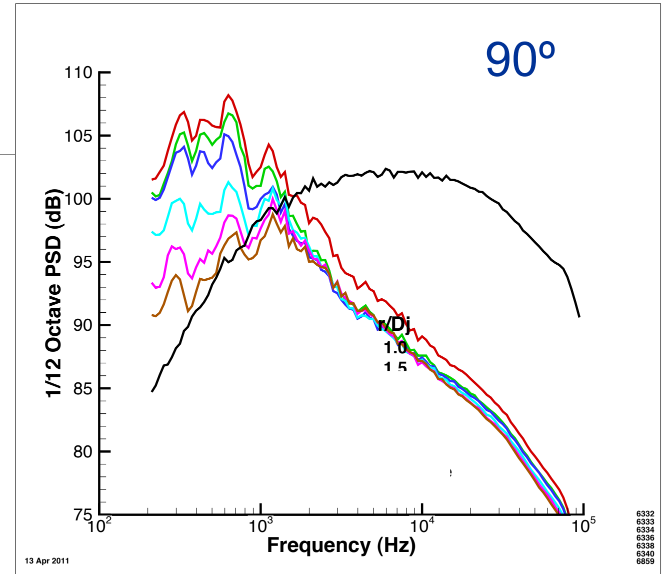
SP7, x/Dj=15

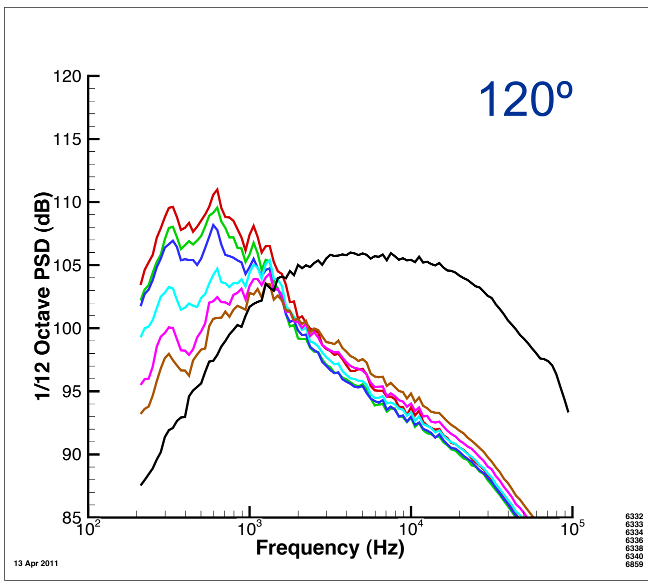




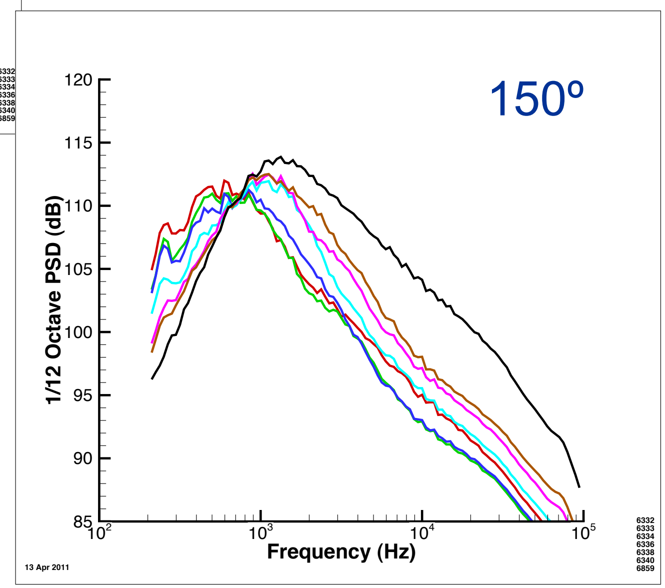
r/Dj ↑







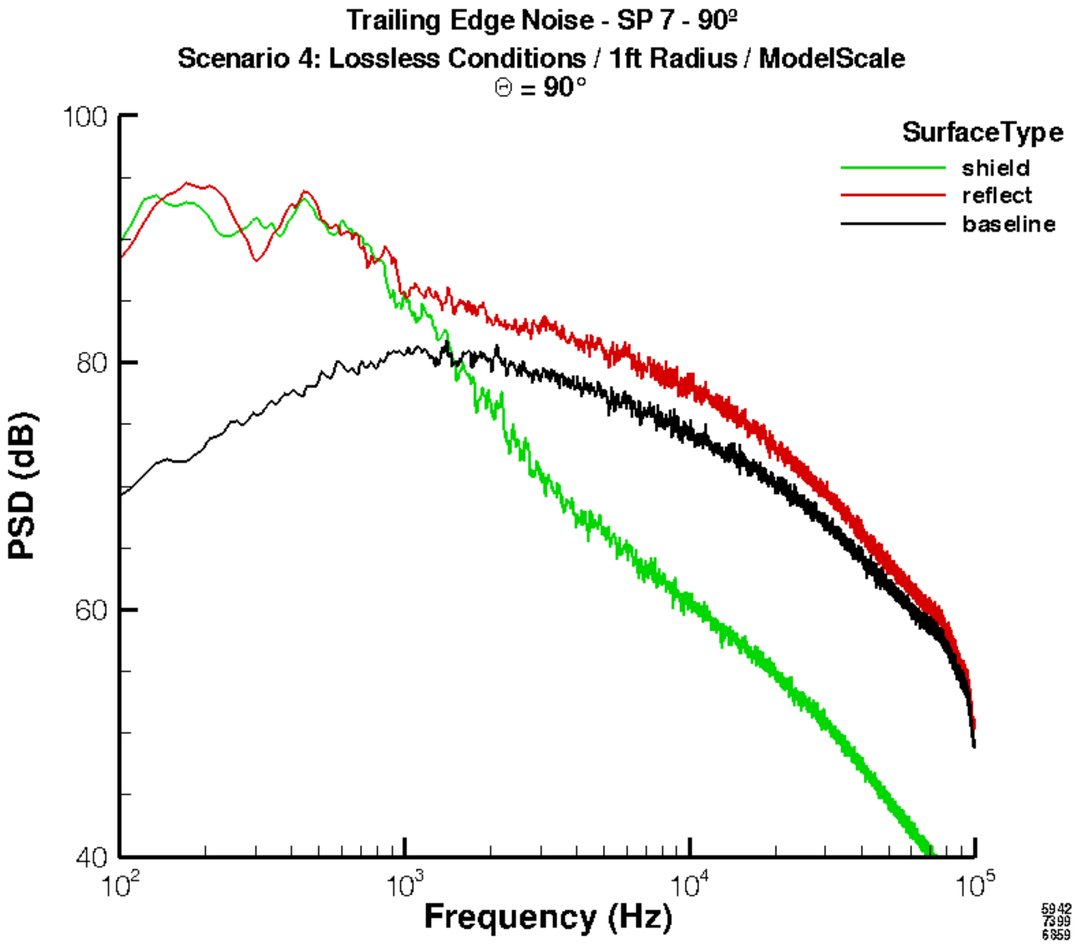
r/D_j=1.0
r/D_j=1.5
r/D_j=2.0
r/D_j=3.0
r/D_j=4.0
r/D_j=5.0
baseline



JSIT Phase 1 - Trailing Edge Noise

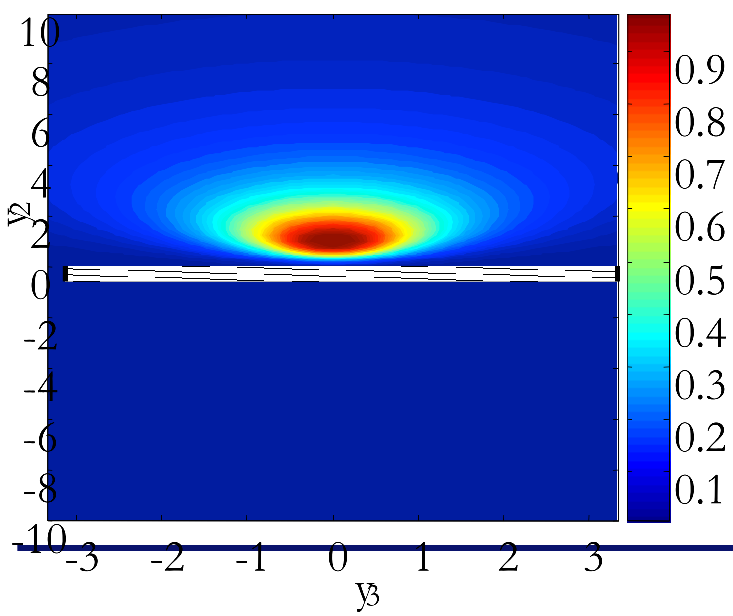
$x_{TE}/D_j = 15$, $r/D_j = 1.5$, SP 7

- Low frequency noise appears on both sides of the jet
- Phased array shows a noise source at the trailing edge
- Is it dependent in any way on the geometry of the trailing edge?
- This is a “region of interest” to understand the physics behind this noise source



Theoretical Work by Afsar and Goldstein

- Rapid-Flow Distortion theory can be used to calculate the sound generated through solid surface interaction
- Gives a very general result that has been applied to the problem of trailing edge noise
- The solution requires the Wiener-Hopf technique which is implemented on conformally mapped equations to facilitate the analysis
- Solution quality is dependent on choice of mapping so cross stream PIV at or near the surface trailing edge would be useful



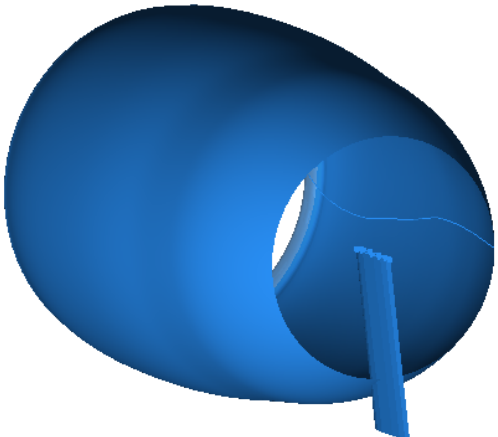
Current status:
We have performed the formal Wiener-Hopf factorization and are going to solve the resulting equation in the low frequency limit since the singularity due to the conformal mapping Jacobian can be dealt with in that limit (maybe).

POC: Mohammed.Afsar@cantab.net

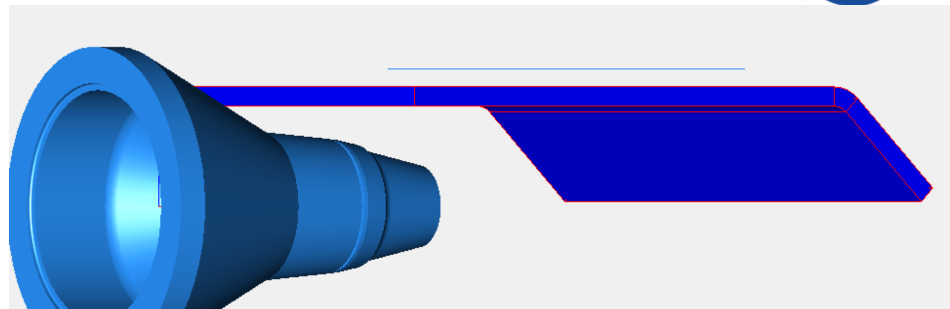
JSIT Phase 2 – Planning

- What should Phase 2 include to be of maximum benefit to developing prediction methods?
- Constraints:
  - Single flow jet, D_j=2”
  - 8 week test window
- More flow conditions?
  - Can do more hot jet conditions but will limit the number of configurations
- More geometric configurations?

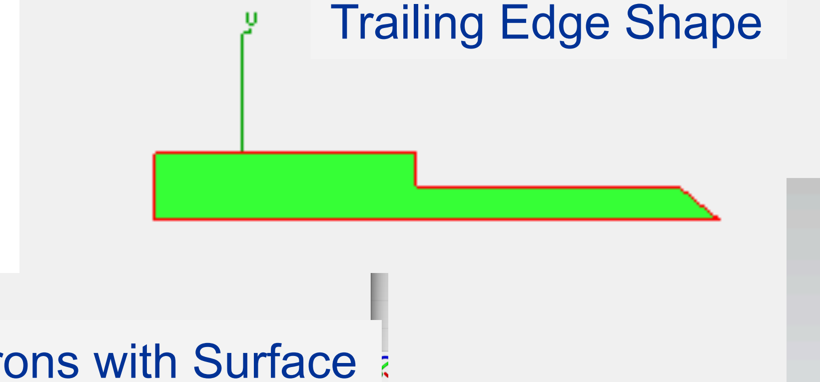
JSIT Phase 2 – More Geometries?



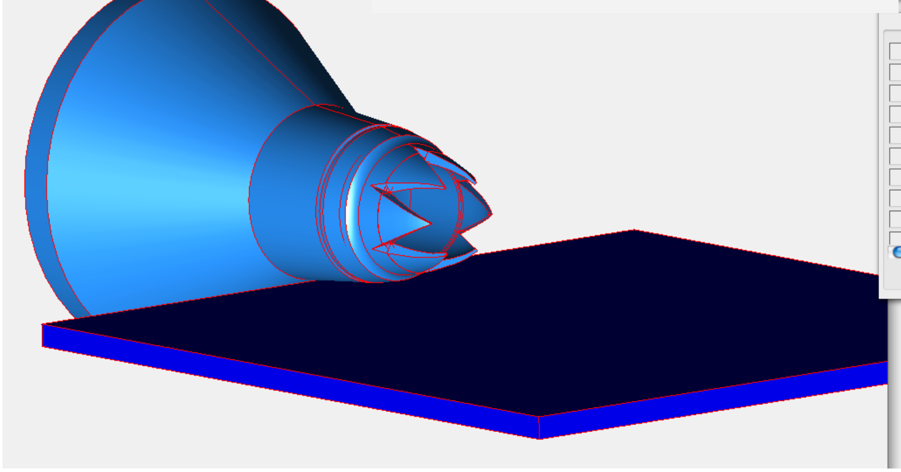
Simple pylon



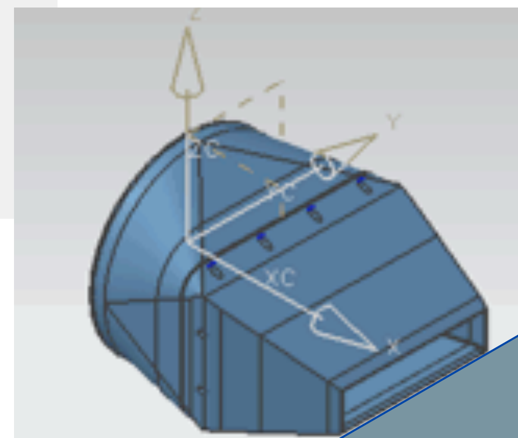
Simple flaps



Trailing Edge Shape



Chevrons with Surface



Rectangular Nozzles

JSIT Phase 2 – Planning

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- Constraints:
  - Single flow jet, D_j=2”
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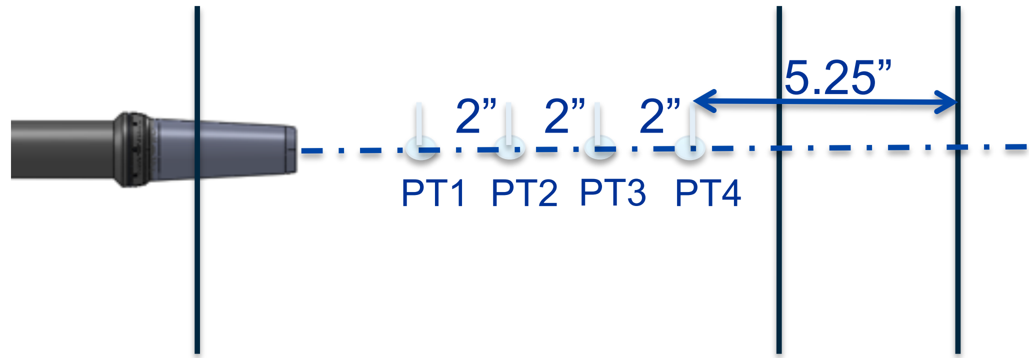
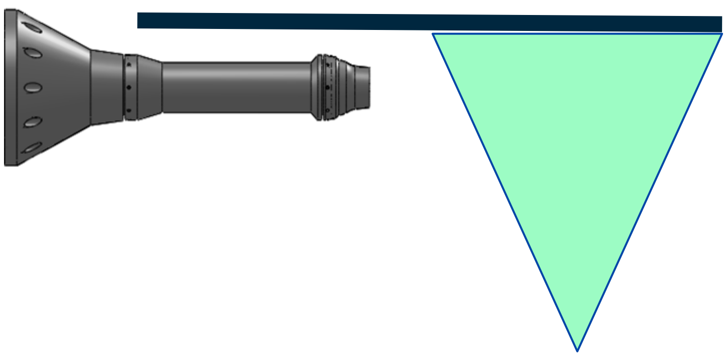
- More flow conditions?
  - Can do more hot jet conditions but will limit the number of configurations
- More geometric configurations?
- More flow measurements?

JSIT Phase 2 – Flow Data?

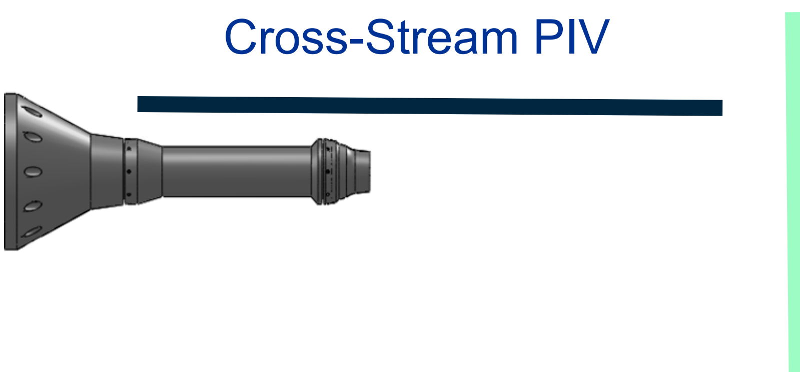
Transient Wall Pressure Measurements



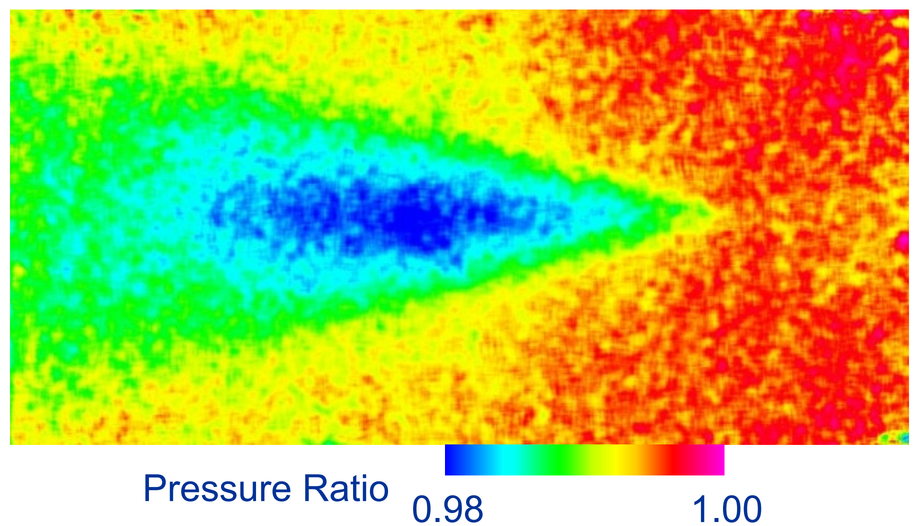
Streamwise PIV



Cross-Stream PIV



Pressure Sensitive Paint



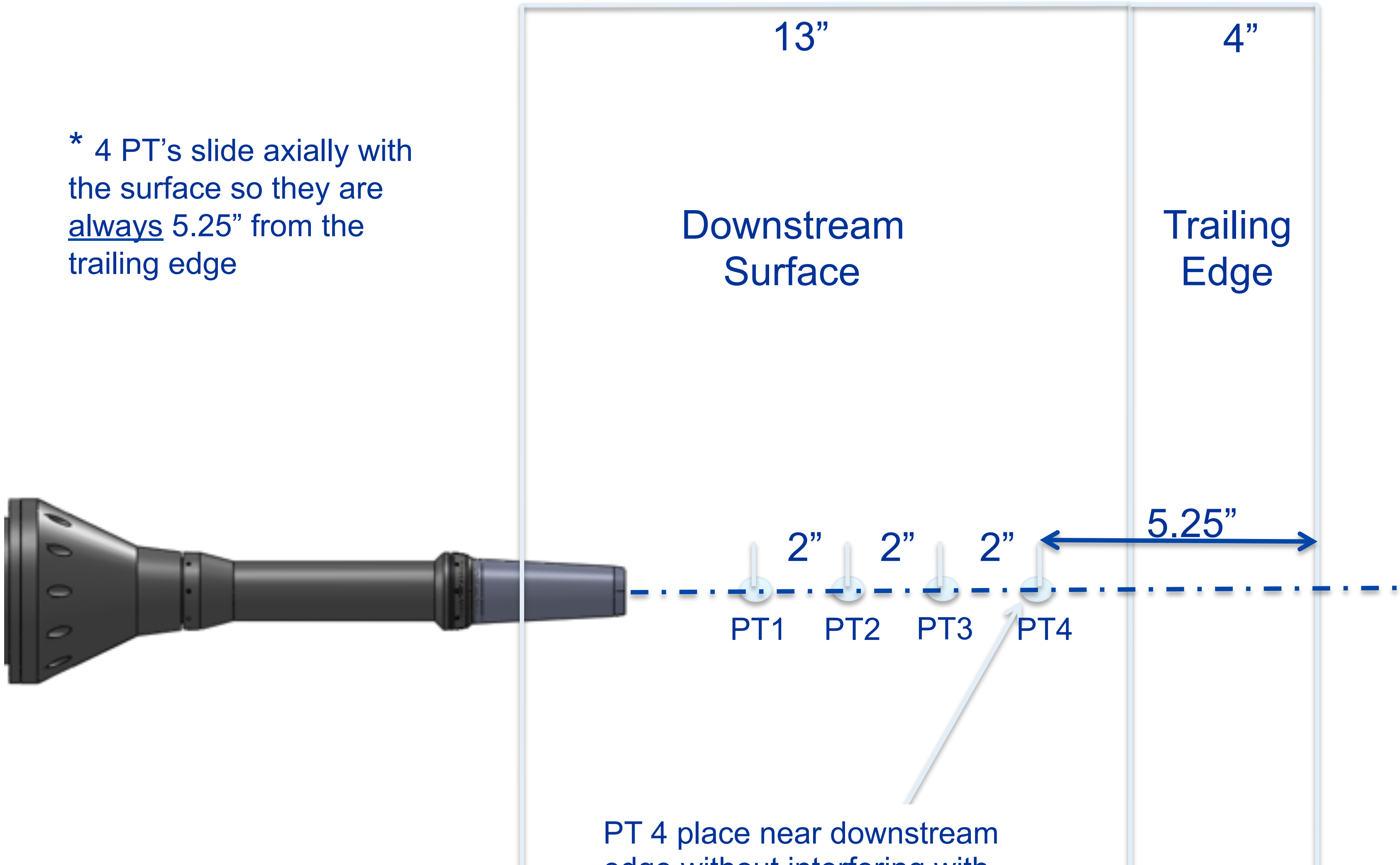
JSIT Phase 2 – Planning

- What should Phase 2 include to be of maximum benefit to developing prediction methods?
- Constraints:
  - Single flow jet, D_j=2”
  - 8 week test window (with possible ? week extension maybe)
- More flow conditions?
  - Can do more hot jet conditions but will limit the number of configurations
- More geometric configurations?
- More flow data?
- Other ideas?
- e-mail: Clifford.A.Brown@nasa.gov

If you are developing a noise prediction code, we need your input?

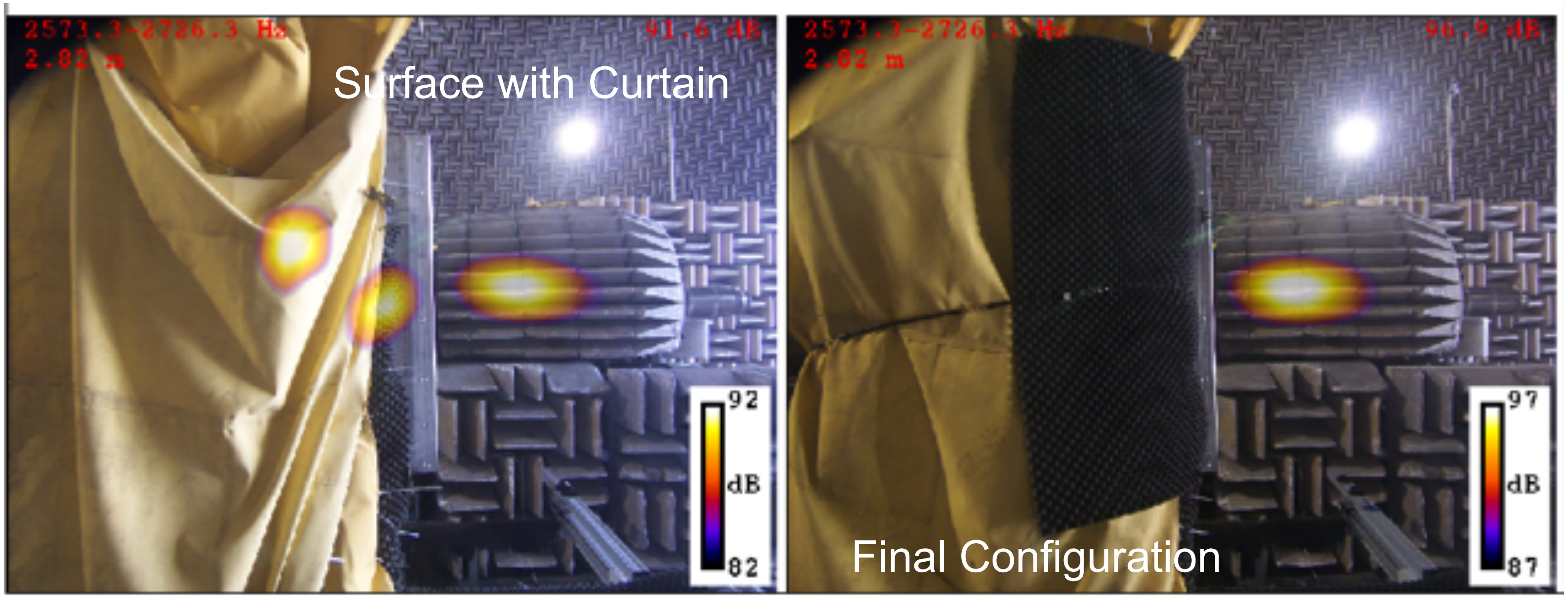
Pressure Transducers from Phase 1

* 4 PT's slide axially with the surface so they are always 5.25" from the trailing edge



PT 4 place near downstream edge without interfering with overlapped mounting of trailing edge plate. Position upstream PT's off PT 4.

Reflections on Back of Surface



- •No sound passing from upstream of surface
- •Curtain alone is a source of sound reflection
- •Curtain is tied back to reduce area for reflection and
- •Eggcrate panel greatly reduces noise reflected to microphone (>10 dB)